भारतीय मानक
Indian Standard

IS 17099 : 2019

भूमिगत कोयला गैसीकरण (यू सी जी) की साइटों का वर्गीकरण

Site Characterization for Underground Coal Gasification (UCG)

ICS 75.020

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March 2019 **Price Group 3**

Methods and Equipments for Underground Coal Gasification and Coal Bed Methane Sectional Committee, MED 37

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Methods and Equipments for Underground Coal Gasification and Coal Bed Methane Sectional Committee had been approved by the Mechanical Engineering Division Council.

Coal gasification has proven itself as a technologically feasible process for gasifying coal, with the potential to be commercially viable under certain conditions. The Large uncertainty about the viability of UCG stems from the unknowns associated with suitable UCG sites. Surface gasification provides a precise process with the ability to control nearly every variable. In contrast, underground gasification relinquishes a significant degree of control for the ability to utilize coal without mining it from the seam. The precision in UCG comes from careful site selection. A gasifier can only rely on coal available within the seam, so there remain a number of critical factors, a developer must consider to ensure the quality and quantity of syngas needed for a project's lifetime.

The composition of the Committee responsible for the formulation of this standard is given at Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

SITE CHARACTERIZATION FOR UNDERGROUND COAL GASIFICATION (UCG)

1 SCOPE

This standard prescribes the:

a) Degree of control for the ability to utilize coal without mining it from the seam.

b) The precision in UCG comes from careful site selection.

NOTE — The referred standard is compilation of critical parameters in site characterization - a developer must consider to ensure quality and quantity of syngas needed for project's life time.

2 GEOLOGY

In-situ coal gasification is a high technology area. Some countries such as UK, USA and Australia have developed their own sets of criteria depending on local conditions. Following important features concerning geology are taken into consideration during site selection for UCG:

a) Geography, topographical and tectonical features of the area;

b) Presence of faults, fractures, fissures etc. and their orientation and extension; and

c) Complete geology and geo data of coal seam as well as roof and floor which include complete lithology of overlying beds, coal bed and the floor rock.

3 COAL RANK

The coal rank under combustion helps determine the quality of the syngas and the feasibility of conducting UCG. Researchers recommend using the lowest ranking coals of lignite and sub bituminous coal or low-rank high volatile bituminous coals. Low-rank coals generally shrink when burned, which improves the connection from the injection to the production wells. However, a trade-off exists between using low rank coals that tend not to swell and high rank coals that have higher heating values, which produce more energy from less coal. Lignites are attractive to UCG because they are more reactive (higher reaction rates).

4 COAL COMPOSITION

The amount of ash, sulfur, and moisture in the coal also affects the quality of the gas. Coal with Ash content above 50 percent decreases the heating value of the coal. Additionally, ash contents above 60 percent can inhibit the UCG process. The higher the sulfur Content, the more the gas will need cleaning to remove impurities. Furthermore, moisture Contents below 15 percent are needed for optimum combustion. Without enough moisture in the Seam, the reaction will need additional water to facilitate the burn. On the other hand, too much Water can reduce syngas quality or even stop the UCG process entirely.

5 COAL POROSITY AND PERMEABILITY

The porosity and permeability of the coal within the coal seam can impede or improve the flow of the syngas between the injection and production wells. Researchers recommend permeability values of 50 to 150 mD. Highly porous coal seams, or highly cleated seams, lead to higher rates of gasification, due to better movement of the gas between the injection and production wells. Alternatively, the faster movement between injection and production wells allows for more water to enter the coal seam, potentially preventing the UCG process. Also, increased porosity and permeability can allow for more syngas to leak out of the coal seam into the surrounding geologic structures, reducing syngas output and increasing the risk of water contamination. Currently, the extent of the effects of porosity and permeability in the coal seam are unknown.

6 PARTINGS

Partings are layers of clay, limestone, shale, sandstone, or other rock that locally separate the coal into multiple layers within a given seam. Partings can be problematic if they are located near ignition points, injection wells and production wells. Researchers recommend a single layer parting should be less than one meter in thickness. With a parting more than one meter thick, the syngas heating value will drop and gasification may prove impossible In addition, a coal seam with over 20 percent of its volume occupied by partings can cause the quality of the gas to decrease to the point that UCG becomes economically impractical.

7 DEPTH AND AQUIFERS

7.1 Optimal coal seam depths exist between 92 to 460 m, with the preference for seams below 200 m to avoid major subsidence issues. Deeper gasification projects are also desirable due to their increased separation from potable groundwater aquifers. Thus, the deeper the coal seam, the less risk of contaminating underground sources of drinking water (USDW). Researchers recommend that aquifers above the coal seam should not be within 25 times the coal seam height. In addition, no overlying strata with water should be within 31 m of the seam.

7.2 There are also problems with drilling wells too deep. The cost of drilling increases at greater depths. More importantly, the pressure on the gas created at deeper depths can alter the gas composition. At greater depths the gas composition may prove inefficient for powering a gas turbine for an electricity plant. In addition, drilling to depths more than 460 m creates complications that restrict the flow of the gas in the coal seam and potentially stop the gasification process.

8 DEPTH AND SUBSIDENCE

Structural integrity of the geologic layers above the coal seam is required to support the overlying strata and the grounds surface. Researchers recommend no less than 15 m of consolidated rock above the coal seam to prevent subsidence from occurring. Additionally, relatively impermeable rock around the seam helps to prevent the escape of product gases, as well as reducing the flow of ground water into the seam.

9 HYDROLOGY

Despite recommendations that no overlying strata with water should exist within 31 m of the Coal seam, some water inflow, whether from surrounding water aquifers, direct injection into the Coal seam, or present within the coal seam, remains necessary to maintain the gasification Reaction. High moisture content in the seam relieves the necessity of surrounding water sources. Lacking high moisture contents, permeable sand stone above the coal seam or within rock layers that are relatively impermeable allow water to flow into the coal seam.

10 COAL SEAM THICKNESS

The thickness of the coal seam should remain between 2 to 15 m with no more than 25 percent Variation in the thickness throughout the coal seam. Variations in thickness can complicate drilling for wells. Greater coal seam thickness leads to higher utilization of the coal seam for gasification. Moreover, researchers have shown that coal seams thicker than 2 meters greatly increase the heating value, and consequently, the amount of energy available in the output gas.

11 COAL SEAM ANGLE (DIP)

The recommended dip or angle of the seam should preferably lie between 0 and 70 degrees with less than 2 degrees in angle variation in order to avoid problems with drilling. As the angle in the seam increases, the potential for damaged equipment and material in the seam rises accordingly. Still, a coal seam with a slight angle is favorable for UCG because it helps to move water and ash away from the area where oxidation occurs.

12 COAL RESERVES AND ACCESSIBILITY

12.1 Depending on the amount of electricity and the life cycle of the power plant, varying amounts of coal are needed to meet the energy requirement.

12.2 For a general reference, using results found in experiments at the Chinchilla plant in Australia, Researchers calculated the amount of coal required to run a 300 MW UCG combined-cycle power plant operating for 20 years with a 50 percent efficiency, producing a syngas with a heating value of 5 MJ/m^3. The researchers found that under the site conditions, 33 million metric tons of coal converts to roughly 75.6 billion m^3 of syngas.

12.3 Some amount of coal must be left in the seam after gasification to prevent large scale collapse of the overburden and subsidence of the ground surface. This limits the amount of coal available in a given site to meet specific energy demands. The amount of coal required depends on specific characteristics of the site, such as the thickness of the coal seam, the structure of the overlying rock, the spacing between the injection and production wells, and the depth underground. For a point of reference, the distance between injection and production wells in the UCG operation Hanna, Wyoming stood between 16 and 18 m. The site in Wyoming successfully gasified 4 600 tons of coal at a depth of approximately 130 m without any subsidence issues or contamination to overlying potable aquifers.

12.4 In addition to underground characteristics, there are other limitations above ground to consider once the production wells begin to receive syngas. Engineers mush take into account available Infrastructure for the gasification process, transportation of syngas, existing land use, environmental and other land-use restrictions when choosing an appropriate site for UCG Development. Researchers suggest that land-use restrictions for UCG most likely present the same restrictions as typical underground coal mines.

13 LAB STUDIES OF GASIFICATION

Lab studies of gasification of the coal under simulated condition should be carried out to help in assessment of injection parameters. Along with temperature measuring devices, tracer such as Argon (Ar) can be used during gasification to understand the in situ phenomenon including cavity growth, to ascertain the other properties of the coals and to assess the impact of the various factors of gasification.

14 WELL COMPLETION/LINKING OF WELLS

14.1 Availability of high temperature resistant (NTR) cement, special completion design, keeping provision for well bore cooling and use of high pressure temperature and corrosion resistant well head, flow line, down hole casing and tubings etc. is a pre-requisite.

14.2 Evaluation of reservoir parameters of coal seam and roof and floor rocks and finding out of most economical and feasible linking technique suiting to the coal seam conditions is a must.

14.3 The main factor determining the cost effectiveness is the specific consumption of linking fluid on a unit of the obtained channel. The intensity of the connecting blast on a burning point depends not only on the consumption of blast injected but also the distance between the injection and burning point, thickness of coal seam, and design of the borehole. Significantly, it also determines the filtration characteristics of the coal rocks and surrounding rocks.

15 CHEMICAL KINETICS/ENVIRONMENTAL STUDIES

Knowledge of chemical kinetics of in-situ gasification, under the prevailing condition of the coal seam, and determination of optimum composition of reactant, that is, air, steam, (O_2), nitrogen (N_2) etc. during reverse combustion as well as forward gasification, is required. Prediction of cavity growth and subsidence etc. during gasification with the help of UCG process models or simulators is also to be done. Identification of required sophisticated capital equipment and instrumentation and their availability for complete UCG process is also necessary. It is also necessary to evaluate environmental impact of UCG process, such as ground water pollution and surface treatment and disposal of produced water and finally to work out economics of the overall process for its commercialization under possible utilization patterns.

16 CHEMICAL ANALYSIS OF COAL

16.1 A comprehensive analysis as given below has to be performed to ensure that the site is suitable. This includes the correlation of the individual coal beds, seam structure, rank and quality of the coal seams:

a) Band by band analysis;
b) Proximate analysis;
c) Ultimate analysis with sulfur distribution;
d) Calorific value;
e) Coking properties;
f) Low temperature gray-king essay;
g) Coal petrography;
h) Ash analysis;
j) Ash fusion temp-range;
k) Coal reactivity;
m) Chlorine and phosphorous content; and
n) Permeability and porosity of coals.

16.2 Table 1 provides recommended values for different parameters associated with UCG:

Table 1 Ideal Characteristics for UCG

(*Clasuse* 16.2)

Parameter	Desired Value	Imperial Units and Comments
Coal thickness (m)	2 - 15	5 - 50ft
Thickness variation (percent of seam thickness)	< 25	—
Depth (m)	92 - 460	300 - 1, 500 ft
Dip (degrees)	0 - 70	—
Dip variation (degrees/31 m, 100 ft)	< 2	—
Single parting thickness (m)	< 1	< 3 ft
Total parting thickness (percent of seam thickness)	< 20	—
Fault displacement (percent of seam thickness)	< 25	—
Fault density (Number of faults/31 m)	< 1	Number of faults/100 ft
Coal rank	Lowrank bituminous	≤ Bituminous

Table 1 (*Concluded*)

Parameter	Desired Value	Imperial Units and Comments
Coal moisture (wt percent)	< 15	—
Ash content (wt percent)	< 50	—
Coal sulfur (wt percent)	< 1	—
Thickness of consolidated overburden	> 15	50 ft
Seam permeability (mD)	50 - 150	—
Immediate overburden permeability (mD)	< 5	15 m (50 ft) above the seam
Distance to nearest overlying water-bearing unit (m)	> 31	> 100 ft
Coal aquifer characteristics	Confined	—
Nearest producing well completed in coal seam (km)	> 1.6	> 1 mile
Available Coal Resources (10^6 m^3)	15.4	543 × 10^9 Cubic ft for 20 year-long operation

ANNEX A

(*Foreword*)

Organization(s)	*Representative(s)*
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Bhel, Hyderabad	Shri D. Satya Mohan Rao
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Central Mine Planning And Design Institute Limited, Ranchi (CMPDI)	Dr Akhilesh Singh
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Gail India Limited	Shri D. M. Rao Dr D. Buragohain (*Alternate*)
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This Indian Standard has been developed from Doc No.: MED 37 (13132).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi